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**ROUTING COOPERATING VEHICLES
TO PERFORM PRECEDENCE-LINKED
TASKS**

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STINFO INTERIM REPORT

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14. ABSTRACT The problem of scheduling cooperating vehicles is a generalization of the classical vehicle routing problem where certain tasks are linked by precedence constraints and vehicles have varying constrained resources. We describe a type of roll-out algorithm that finds an approximate solution to the problem in real-time and demonstrate the results of the computational experiments.							
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Routing Co-operating Vehicles to Perform Precedence-linked Tasks

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Problem description

- **Multiple Vehicle Orienteering Problem:**

Given a set of vehicles and sites with rewards, maximize the total number of rewards collected subject to hard time constraint

- Closely related to Vehicle Routing Problem (VRP)

- **Co-operating vehicle orienteering problem:**

Certain sites must be visited multiple times to perform various tasks in given order.

Applications

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- **Synchronized vehicle dispatch [Rousseau, Gendreau, Pesant, 2002]**

- Transportation of disabled persons
- Hardware/software installation

- **Military applications:**

- Shoot – look – shoot sequence
- Standoff jamming

- **Problems of real-time nature**

Solution Methods

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- Local search techniques
 - Tabu search
- Constrained programming

Problem Formulation

- **Given:**

- **Heterogeneous vehicle fleet.**

For each vehicle:

- Initial and terminal positions
- Time constraint
- Vehicle type

- **Site set.**

For each site:

- Task sequence and vehicle type per task
- Travel times to all other sites and initial/terminal vehicle positions per vehicle type
- Precedence constraint per task pair: (min, max) times between tasks
- Reward collected by performing each task

Problem Formulation (cont'd)

Maximize:

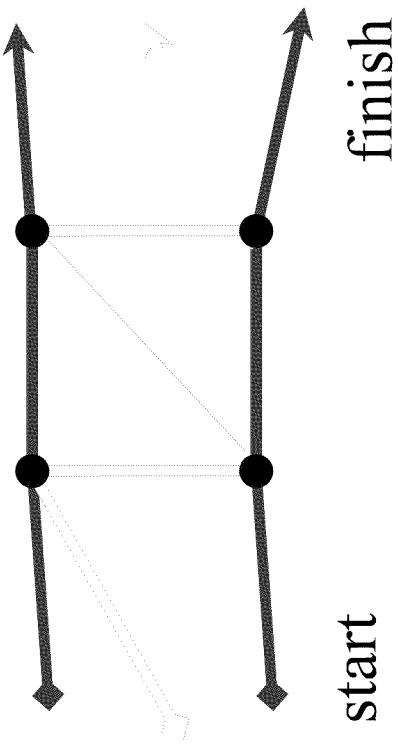
Total collected reward

Subject to:

- Initial/terminal positions of the vehicles
- Travel time constraints
- Task precedence

Example

- Three vehicles to visit four sites, two ordered tasks per site
- Two type I vehicles;
One type II vehicle



Roll-out Algorithm

- Heuristic tree search using so-called “base heuristic”
- Start with an empty partial solution
- At each iteration:
 - Given a partial solution
 - Construct M candidate extensions of a partial solution
 - Roll-out move:
 - Evaluate each candidate extension by applying the base heuristic
 - Select the best candidate and re-iterate
- Stop when a complete solution is obtained
- Variation: At each iteration use W partial solutions to extend

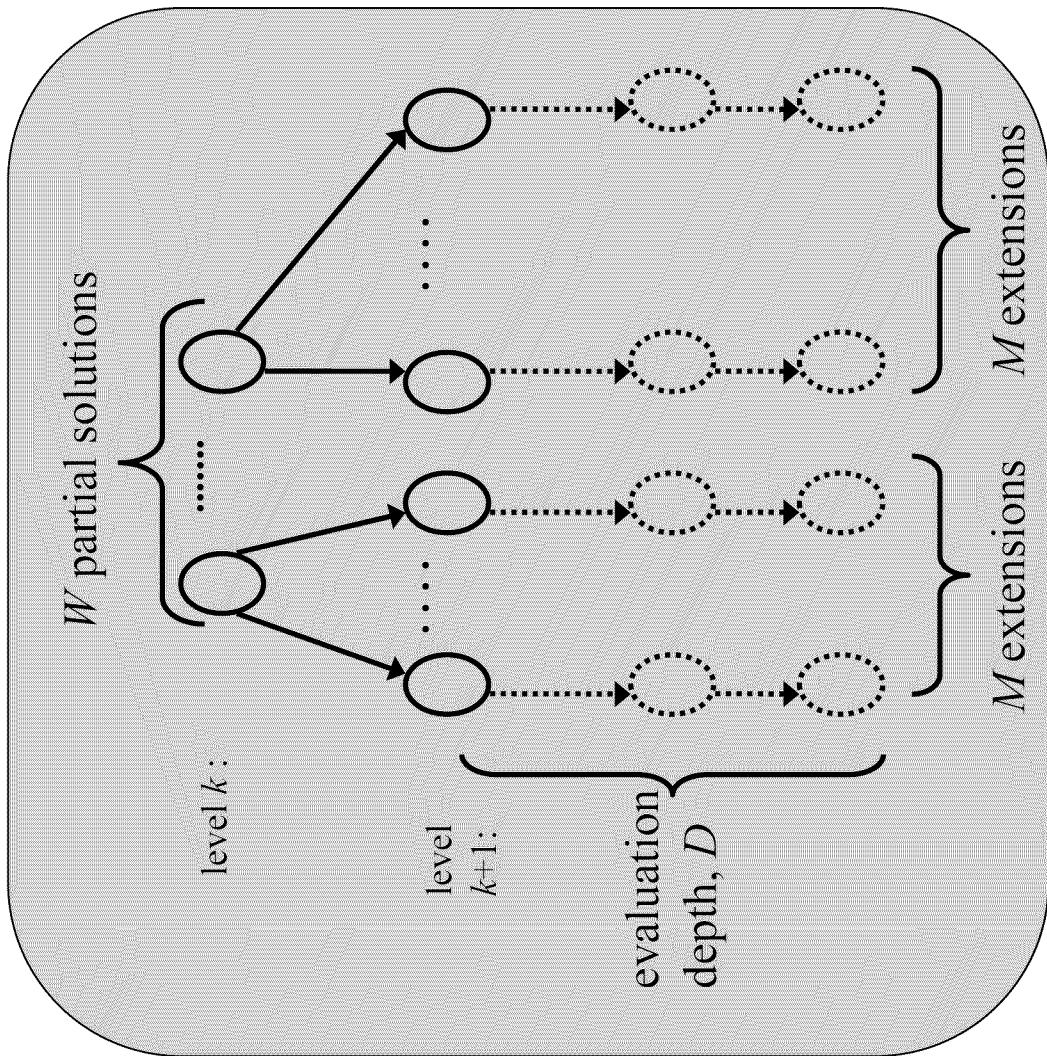
Roll-out approach: a single iteration

- Base heuristic: generate D sequential greedy solution extensions

- Algorithm running time:

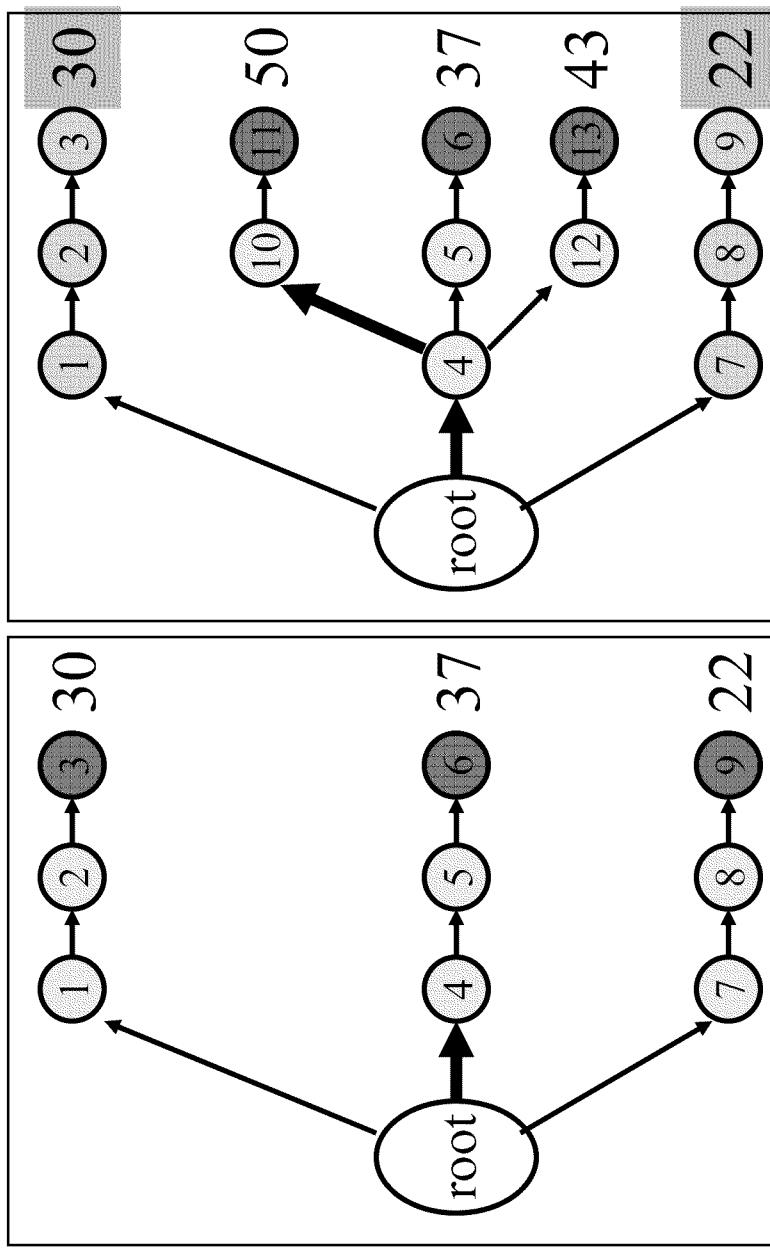
$$O(WMDT(\text{GH}))$$

where $T(\text{GH})$ is the time spent on a single greedy extension



Roll-out approach: Limited Tree Search

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Complete Solution
solutions: values:

Numbers inside the circles indicate the order, in which the corresponding nodes are generated

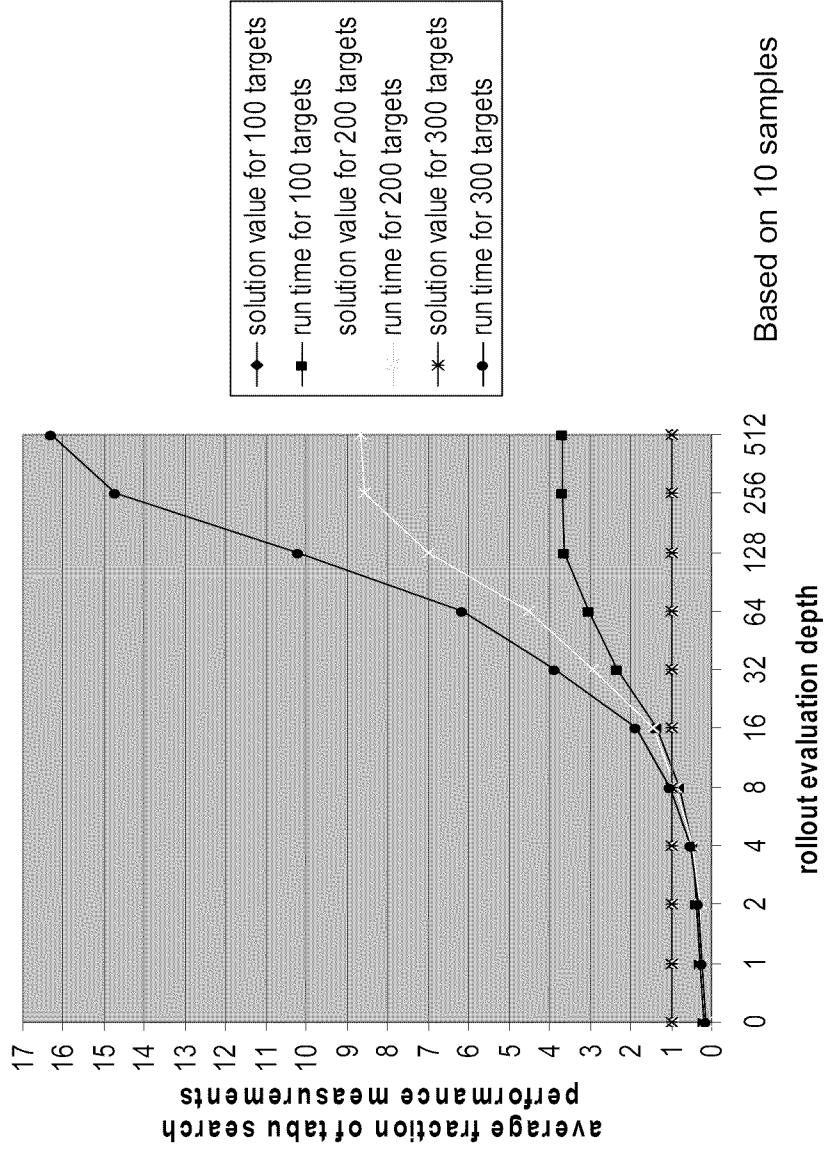
Roll-out algorithm application to routing co-operating vehicles

- **Partial solution:**
 - Sequence of site visits per vehicle subject to precedence and time constraints and terminal position reachability
 - At least one task can be added to at least one vehicle
- **Task availability:**
 - Given a partial solution, task is available if adding it does not violate precedence/time constraints
- **Solution extension:**
 - One available task is added to one vehicle
- **Base heuristic:**
 - Select an available task to maximize reward per travel time

Experimental results: evaluation depth, D

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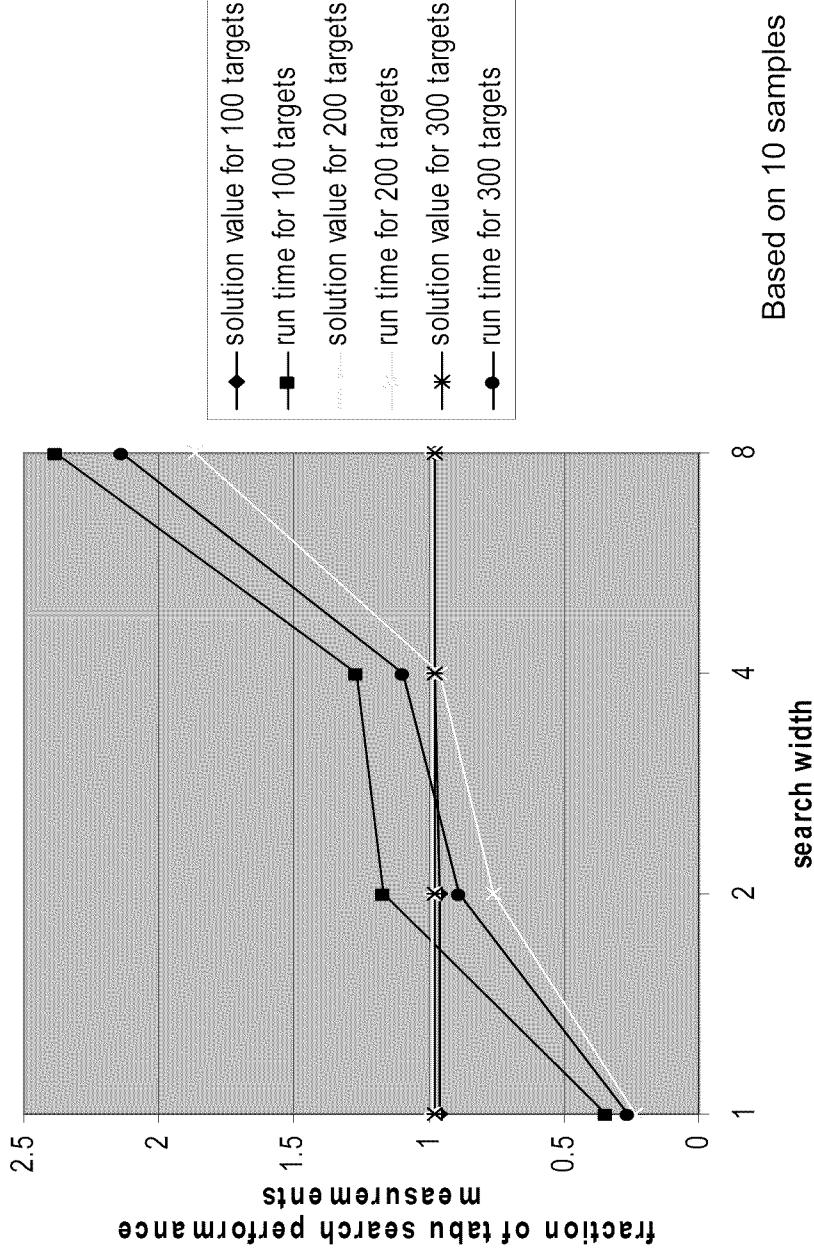
Rollout algorithm performance as compared to modified
tabu search method



Experimental results: search width, W

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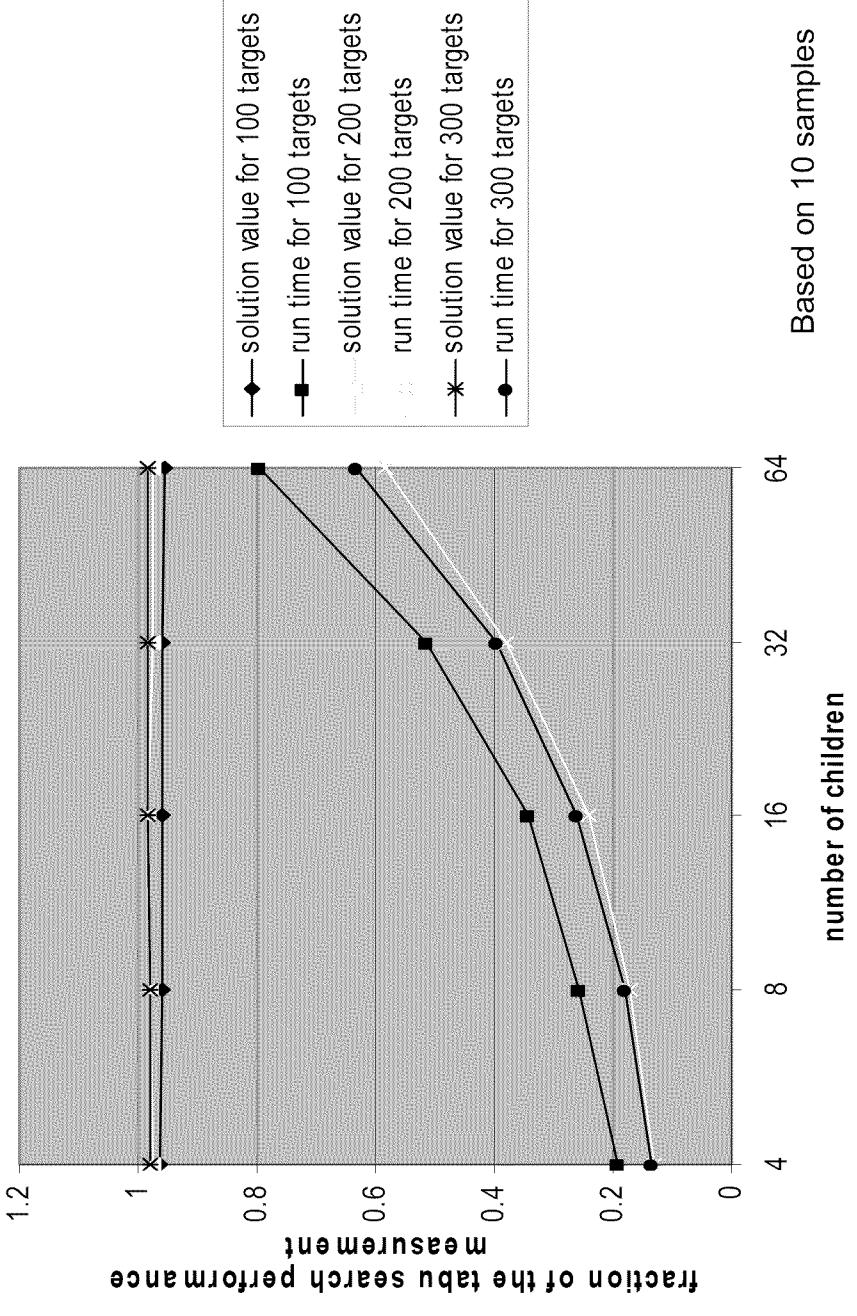
rollout algorithm performance as a function of search width



Experimental results: number of candidate extensions, M

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rollout algorithm performance as a function of number of children



Conclusion

- High-quality solution as compared with tabu search
- Scalable algorithm
- Applicable to real-time scheduling by adjusting parameters to speed-up computation
- Applicable to limited-horizon routing under uncertainty in fast changing environment